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Characterization and classification of soil resources of Balapur micro-watershed

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Abstract: A study was undertaken to characterize and classify the soil resources of Balapurmicro-watershed in Koppal district of Karnataka. Seventeen profiles were studied for the morphological, physical and chemical properties. Ten representative pedons covering all the soil types were selected and classified. The soils were very shallow to deep in depth, dark reddish brown to yellowish red in red soils, where as in black soils shown very dark brown to very dark grey brown in colour. Soils under the study were predominantly sub-angular blocky in structure, sandy clay to clay in texture, neutral to slightly alkaline in reaction with non-saline soils and organic carbon content was low. Calcium and magnesium were the dominant exchangeable cations followed by sodium and potassium. Soils studied were classified up to family level according to revisions in Soil Taxonomy using morphological, physical and chemical properties. Major proportion of the soils in the micro-watershed belonged to the order Inceptisols, Alfisols and Vertisols.

Keywords: Soil characterization, Soil classification, Soil resources, Soil survey

Introduction

The natural resources of any country are the national treasure and need proper planning to make best use of them. Therefore, sustainable management practices are urgently needed all over the world to preserve the production potential of agricultural lands. Efficient management and maintenance of soil health is the key to accomplish sustained high productivity, food security and environment safety. Yadav (2003) reported that per capita arable land in India decreased from 0.34 ha in 1950-51 to 0.15 ha in 2000-01 and is expected to shrink to 0.08 ha in 2005. No possibility of further horizontal expansion in the cultivated area seems to exist. It has been also reported that 57 per cent of the total geographical area in India is suffering from various types of land degradation problems.

Soil survey constitutes a valuable resource inventory linked with the survival of life on the earth. It provides an accurate and scientific inventory of different soils, their kind and nature, and extent of distribution so that one can make prediction about their character sand potentialities. It also provides adequate information in terms of land form, slope, land use as well as characteristics of soils (*viz.,* texture, depth, structure, stoniness, drainage, acidity, salinity *etc.*) which can be utilized for the planning and development. Keeping this in mind, a rapid reconnaissance soil survey of the area was carried out to characterize and classify soils of Balapur micro-watershed in Koppal district of Karnataka for sustainable land use planning using geo-referredfalse colour composite image of IRS-P6 LISS-IV and Survey of India (SOI) topo maps.

Material and methods

The selected Balapur micro-watershed lies 25 km away from Koppal district. The Balapur micro-watershed is located between 15^0 31' 15.6" and 15^0 33' 12.9" N latitude and 76^0 06' 11.6" and 76^0 07' 43" E longitude with an average elevation of 578 m above Mean Sea Level (MSL). The climate is semi-arid with a mean annual average rainfall of 572 mm. Granite-gneiss is the parent rock in the study area. The area is under Ustic moisture regime and Isohyperthermic temperature regime. Soil survey was carried out using IRS P6 LISS-IV imagery, survey of India topo sheet and cadastral map of the village. After intensive traversing, 17 pedons were studied depending upon soil heterogeneity. Morphological characters like colour, structure, consistency and physico-chemical properties like bulk density, water holding capacity, pH, electrical conductivity, organic carbon, cation exchange capacity, etc., were studied for the profile samples. The soils were classified at family level according to revisions in soil taxonomy (Anon., 2014). After correlating for the above referred properties of pedons, ten representative pedons were selected and presented in the paper.

Results and discussion

The morphological properties of the pedons have been shown in Table 1.The soils were dark reddish brown (2.5YR 3/4) to yellowish red (5YR 4/6) in pedons 2, 3, 4, 6, 9, 11 and 13, whereas in pedon 10 and 17 very dark brown (7.5YR 2.5/3) to light brown (7.5YR 6/3). There was not much variation in the soil colour with depth in all the pedons except in pedon 9. This variation in colour is a function of chemical and mineralogical composition, topographic position, textural makeup and moisture regimes of the soils. The results of the present study are in accordance with the findings of Thangasamy *et al.* (2005), which also indicated the gradation in the colour from higher topographic position to the lower topographic units. The soils exhibited moderate medium crumb to sub-angular blocky structure in the surface, whereas in sub-surface horizon it was medium, moderate to strong sub-angular blocky structure. The structure designates the mode of arrangement of the particles and their aggregation, therefore the structural variation in soils was useful to differentiate the horizon.

The consistence of all the pedon soils varied from slightly hard to hard when dry, friable to firm when moist, slightly sticky to very sticky and slightly plastic to very plastic when wet. This physical behavior of soils influenced by dry, moist and wet conditions was not only due to the textural make up but also due to type of clay minerals present in these soils (Thangasamy *et al.,* 2005 and Dasog and Patil, 2011). Many to

Table 1. Soil morphological characteristics of pedons in Balapur micro-watershed

Horizons	Depth (cm)	Munsellcolour Dry	Munsellcolour Moist	Texture	Structure	Consistency Dry	Consistency Moist	Consistency Wet	Roots	Boundary	Special features
Pedon 2											
Ap	0-17	5YR 4/6	5YR 4/4	scl	2m sbk	sh	fr	ms&mp	mf	cs	Clay skins on peds
B_1w	17-43	5YR 4/4	5YR 4/4	cl	2m sbk	h	fr	ms&mp	cf	gw	were observed at
B_2t	43-63	5YR 3/3	5YR 4/6	cl	2m sbk	sh	fr	ss&mp	ff	gw	43-63 cm & depth
BC	63-80	5YR 4/6	5YR 4/4	sc	2m sbk	sh	fr	ms&sp	ff	gw	
Cr	80+				Weathered bed rock						
Pedon 3											
A_1	0-7	2.5YR 3/4	2.5YR 2.5/4	scl	2m sbk	sh	fr	ss&sp	mf	as	Weathered granite-
Bw_1	7-22	2.5YR 3/4	2.5 YR 3/3	sc	2m sbk	sh	fr	ss&sp	mf	gw	gneiss observed at
Bw_2	22-43	2.5YR 3/4	2.5YR 3/3	sc	2m sbk	sh	fr	ss&sp	mf	cw	depth 43+
Cr	43+				Weathered bed rock						
Pedon 4											
Ap	0-14	2.5YR4/6	2.5YR 3/4	sc	2m sbk	sh	fr	ms&mp	mf	cs	Clay skins on peds
B_1w	14-47	2.5YR 3/4	2.5YR 2.5/4	cl	2m sbk	sh	fr	ms&mp	mf	cs	were observed at
B_2t_1	47-74	2.5YR 4/6	2.5YR 3/6	c	1m sbk	sh	fr	ms&mp	ff	cs	47-104 cm depth
B_2t_2	74-104	2.5YR 4/6	2.5YR 3/6	c	1m sbk	sh	fr	ms&mp	ff	cs	
Cr	104+	Weathered bed rock									
Pedon 6											
Ap	0-20	2.5YR 3/6	2.5YR 2.5/4	c	2m sbk	sh	fr	ss&mp	mf	cw	Weathered granite-
Bw	20-41	2.5YR 3/4	2.5YR 2.5/4	cl	3m sbk	h	fr	ss&mp	mf	gw	gneiss observed at
BC	41-50	2.5YR 3/4	2.5YR 2.5/3	sc	3m sbk	h	fr	ss&mp	ff	gw	depth 50+
Cr	50-75+	Weathered bed rock									
Pedon 9											
Ap	0-12	5YR 4/6	5YR 3/4	scl	2m sbk	sh	fr	ss&mp	mf	cs	Clay skins on peds
B_1w	12-53	2.5YR 3/4	2.5YR 2.5/4	scl	2m sbk	sh	fr	ss&mp	ff	gw	were observed at
B_2t	53-93	2.5YR 4/6	2.5YR 3/4	sc	2m sbk	sh	fr	ss&mp	ff	gw	53-93 cm depth
BC	93-107	2.5YR 4/6	2.5YR 3/3	sc	2m sbk	sh	fr	ss&mp	ff	gs	
Cr	107+	Weathered bed rock									
Pedon 10											
Ap	0-20	7.5 YR 3/4	7.5YR 4/3	c	1f cr	sh	fr	ss&mp	mf	cs	Pressure faces and
Bss_1	20-50	7.5 YR 2.5/3	7.5YR 3/2	c	3m sbk	h	fr	ms&mp	mf	gw	cracks were
Bss_2	50-70	7.5YR 4/4	7.5YR 3/3	c	3m sbk	h	fr	ms&sp	ff	gw	observed at 20-70
BC	70-80	7.5YR 4/3	7.5YR 4/2	sc	2m sbk	h	fr	ms&mp	ff	gw	cm depth
Cr	80+	Weathered bed rock									
Pedon 11											
Ap	0-13	2.5YR 4/6	2.5YR 3/4	scl	1f cr	sh	fr	ss&sp	mf	cs	Clay skins on peds
B_1w	13-33	2.5YR 3/6	2.5YR 3/4	scl	2m sbk	h	fr	ms&mp	ff	cs	were observed at
B_2t_1	33-77	2.5YR 3/4	2.5YR 2.5/3	sc	3m sbk	sh	fr	ms&mp	ff	cs	33-110 cm depth
B_2t_2	77-110	2.5YR 3/6	2.5YR 4/6	sc	1f sbk	sh	fr	ms&vp	ff	cw	
Cr	110+	Weathered bed rock with moderate effervescence									
Pedon 13											
Ap	0-18	5YR 4/6	5YR 3/3	scl	2m cr	sh	fr	ss&sp	mf	cs	Weathered granite-
Bw_1	18-37	5YR 3/4	5YR 3/3	c	3c sbk	h	fr	ss&sp	mf	gw	gneiss observed at
Bw_2	37-63	5YR 4/4	5YR 3/3	c	3m sbk	h	fr	ss&sp	ff	gw	depth 72-85
BC	63-72	5YR 4/4	5YR 3/3	sc	2m sbk	h	fr	ss&sp	ff	gw	
Cr	72-85+	Weathered bed rock									
Pedon 16											
Ap	0-13	2.5YR 3/4	2.5YR 2.5/4	scl	1f sbk	sh	fr	ms&mp	mf	cs	Weathered granite-
Bw_1	13-30	2.5YR 3/6	2.5YR 2.5/4	sc	1m sbk	sh	fr	ms&mp	mf	cs	gneiss observed at
Bw_2	30-51	2.5YR 3/6	2.5YR 2.5/4	c	2m sbk	h	fr	ms&mp	cf	gw	depth 78-90+
BC	51-78	2.5YR 4/6	2.5YR 3/4	sc	2c sbk	h	fr	ms&mp	ff	gw	
Cr	78-90+	2.5YR 3/4	2.5YR 2.5/3	scl	2c sbk	h		ss&sp	ff	gw	
Pedon 17											
Ap	0-15	7.5YR 2.5/3	7.5YR 3/2	c	1f cr	sh	fr	ms&mp	mf	cw	Pressure face and
Bss_1	15-50	7.5YR 3/1	7.5YR 4/1	c	3m sbk	h	fi	vs&mp	cf	gs	cracks were
Bss_2	50-88	7.5YR 3/2	7.5YR 3/1	c	3m sbk	vh	fi	vs&mp	ff	cw	observed at 15-90
BCk	88-102	7.5YR 6/3	7.5YR 4/4	sc	0f sbk	sh	vfi	ss&mp	ff	cw	cm depth with
Crk	102+	5YR 4/6	5YR 5/6	-	-	s	vfi	-	-	-	slight to violent effervescence down the depth

few and fine sized roots were observed in all the pedons of surface and sub-surface horizons. In pedons 2, 4, 9 and 11 clay skins were observed on the peds due to illuviation of clay, whereas in pedon 10 and 17 slicken sides and cracks in the soil were observed. The cracks vary in width from 1 to 10 cm, extending to depth > 50 cm. The cracks remained open for periods varying from 90 to 150 cumulative days. Abundant accumulation of calcium carbonate concretions were observed in sub-surface horizon of pedon 17. Physical characteristics of the soil are presented in Table 2.

In red soil pedons the texture varied from clay, clay loam, sandy clay loam to sandy clay. The texture was clay loam because of lesser mobilization and translocation of finer fractions. Similar finding were reported by Pulakeshi *et al.* (2014). The major area of red soil pedons varied between clay to sandy clay. The black soil pedons were clay in texture, in general, morphogenetic expression of most of the black soils showed considerable homogeneity. However, prominent slicken sides were observed at depth >30 cm in all black soil pedons. These findings were in conformity with the observations of Dasog and Patil (2011). The clay content increased throughout the depth in all the pedons and the study could be attributed to several processes like illuviation of the finer fraction to the lower depth. Similar results were quoted by Pulakeshi *et al.* (2014) for the soils of Mantagani village of Haveri district in Karnataka. The distribution of silt content did not follow definite trend in the pedons under study. Generally, Sand content was more in the surface compared to sub-surface horizons. The sand content was much higher than the silt and clay fractions. That indicates the coarser fractions dominate in silicaceous, granite gneiss parent material. High clay and silt content in some of the pedons of study area may be due to their formation on the transported parent material. Similarly, the illuvation process also affected the vertical distribution of silt and sand content. Similar observations were also made by Sharma *et al.* (2004).

Water holding capacity of various pedons ranged from 30.11 to 54.2 per cent. These differences were due to the variation in clay and organic carbon content of the pedons. Maximum water holding capacity followed the trend of clay. Similar results were reported by Thangasamy *et al.* (2005) in soils of Savagiri micro-watershed in Chittor district of Andhra Pradesh. In black soil pedons, the bulk density varied from 1.24 to 1.46 Mg per m^{-3}. Bulk density of the pedon samples varied from 1.22 to 1.57 Mg m^{-3} followed a common pattern of increasing with increasing depth. It was attributed to the pressure of the overlying horizons and diminishing amounts of organic matter. Similar results were quoted by Marathe *et al.* (2003) in mandarin orchards of Nagpur and in rice soils of eastern region of Varanasi (Singh and Agrawal, 2005).

The pH of red soil pedon ranged from neutral to slightly alkaline and from alkaline to strongly alkaline in black soil pedons (Table 4). High pH value in black soil pedons was due to nature and the accumulation of the bases in the solum as they were poorly drained. Similar observation was made by Dasog and Patil (2011). The KCl pH values were lower than the water pH values and the difference between KCl pH and water pH value (more than -0.5) indicates a high negative surface charge density in these soils (Sitanggang *et al.,* 2006). In soils of all the pedons, EC ranged from 0.02 to 0.36 dS m^{-1} indicating non-saline nature of soils. and did not show any specific relationship with depth. This may be due to free drainage conditions, which removed the released bases by the percolating and drainage water. These results were in confirmation with the findings of Manojkumar Dabi (2011).

Free calcium carbonate varied from 18.75 to 61.25 g kg^{-1}. The per cent calcium carbonate in soils increased with depth. In semi-arid condition calcium and magnesium get precipitated as their carbonates and bicarbonates. The exchangeable bases in all the pedons were in the order of Ca^{+2}> Mg^{+2}> Na^{+}> K^{+} on the exchange complex. From the distribution of Ca^{+2} and Mg^{+2}, it is evident that Ca^{+2} showed the strongest relationship with all the species, comparing these ions (Ca^{+2}, Mg^{+2}, K^{+} and Na^{+}) it was clear that Mg^{+2} ions were present in low amount than Ca^{+2} ions. The low value of exchangeable monovalents, compared to divalents was due to preferential adsorption of divalents than monovalent.

Cation exchange capacity of the pedons varied both location-wise and depth-wise. It varied from 12.73 to 41.23 cmol (p^{+}) kg^{-1}. The values of cation exchange capacity of soils increased with profile depths and followed the trend of clay content. There was a high degree of correlation between clay and CEC in both red and black soils. The exchangeable sodium per cent (ESP) ranged from 1.31 to 5.01 per cent indicated initiation of the process of sodiumization in a downward direction. A measure of relative amounts of exchangeable sodium in comparison with the total cations in the soil are dependent on factors such as type of minerals, concentration of electrolytes and status of soluble cations.

The soils in the Balapur micro-watershed were highly base saturated. The base saturation was high in all surface horizons. In most of the soils, the base saturation increased with the depth. The increase of base saturation with the depth is due to the downward movement of bases along with percolating water from the upper horizon to the lower horizons. Similar results were found by Sitanggang *et al.* (2006). Based on morphological characteristics of the pedons, physical, chemical characteristics of the soils and climate of the area, seventeen pedons from the study area were classified up to the family level according to the criteria laid down by the Soil Survey Staff (2014).

Pedons 2, 3, 4, 9 and 11 have argillic sub-surface horizon and do not have plaggan epipedon and spodic or oxic sub-surface horizons above the argillic horizon. Further, the argillic horizon was developed due to clay illuvation and was identified by the presence of clay cutans and the thickness of the horizon was more than 7.5 cm and also more than one-tenth as thick as the sum of the thickness of all the overlying horizons. The base saturation was more than 35 per cent throughout the depth of the horizon. Hence, Pedons 2, 3, 4, 9 and 11 are keyed out as Alfisol at order level. Pedon 6, 13 and 16 were classified into Inceptisols owing to the absence of any other diagnostic horizons other than cambic horizon. Pedons 10 and 17 were

Table 2. Physical properties of Balapur micro-watershed pedons

Horizon	Depth (cm)	Total sand (2.0-0.05 mm)	Silt (0.05-0.02 mm)	Clay (<0.002 mm)	B.D (Mg m^{-3})	MWHC (%)
			%			
Pedon 2						
Ap	0-17	48.0	20.6	31.4	1.25	44.18
B_1w	17-43	40.2	26.6	33.2	1.38	51.00
B_2t	43-63	42.8	18.2	39.0	1.40	47.02
BC	63-80	67.3	10.1	22.6	1.45	38.68
Cr	80+			Weathered granite-gneiss		
Pedon 3						
A_1	0-7	62.3	10.3	27.4	1.32	34.70
Bw_1	7-22	48.5	8.2	43.3	1.35	43.24
Bw_2	22-43	51.1	10.1	38.8	1.37	47.39
Cr	43+			Weathered granite-gneiss		
Pedons 4						
Ap	0-14	49.7	16.6	33.7	1.28	36.14
B_1w	14-47	39.9	22.6	37.5	1.37	48.62
B_2t_1	47-74	44.6	6.1	49.3	1.40	42.66
B_2t_2	74-104	44.2	10.2	45.6	1.45	40.46
Cr	104+			Weathered granite-gneiss		
Pedon 6						
Ap	0-20	40.6	16.8	42.6	1.28	39.39
Bw	20-41	37.9	22.6	39.5	1.36	50.45
BC	41-50	49.7	14.5	35.8	1.42	46.56
Cr	50-75+			Weathered granite-gneiss		
Pedon 9						
Ap	0-12	54.8	18.3	26.9	1.26	31.02
B_1w	12-53	56.3	10.3	33.4	1.33	35.62
B_2t	53-93	47.5	12.5	40.0	1.37	37.57
BC	93-107	52.6	16.3	31.1	1.58	37.61
Cr	107+			Weathered granite-gneiss		
Pedon 10						
Ap	0-20	43.6	12.4	44.0	1.32	42.94
Bss_1	20-50	38.6	8.1	53.3	1.35	45.22
Bss_2	50-70	41.3	10.0	48.7	1.39	50.99
BC	70-80	51.5	12.0	36.5	1.50	51.43
Cr	80+			Weathered granite-gneiss		
Pedon 11						
Ap	0-13	50.9	22.3	26.8	1.38	32.10
B_1w	13-33	48.4	18.4	33.2	1.36	31.45
B_2t_1	33-77	45.3	12.5	42.2	1.39	37.26
B_2t_2	77-110	51.0	8.1	40.9	1.53	37.36
Cr	110+			Weathered granite-gneiss		
Pedon 13						
Ap	0-18	62.5	8.2	29.3	1.35	30.11
Bw_1	18-37	46.3	12.3	41.4	1.36	42.69
Bw_2	37-63	42.5	14.3	43.2	1.38	52.87
BC	63-72	50.8	8.1	41.1	1.46	48.85
Cr	72-85+			Weathered granite-gneiss		
Pedon 16						
Ap	0-13	52.2	14.4	33.4	1.32	37.94
Bw----$_1$	13-30	44.2	16.4	39.4	1.34	40.25
Bw_2	30-51	38.8	18.2	43.0	1.41	48.14
BC	51-78	57.3	12.1	30.6	1.52	49.06
Cr	78-90+			Weathered granite-gneiss		
Pedon 17						
Ap	0-15	34.0	12.7	53.3	1.35	43.49
Bss_1	15-50	32.8	10.1	57.1	1.38	52.44
Bss_2	50-88	31.8	16.9	51.3	1.40	54.88
BCk	88-102	51.2	8.1	40.7	1.57	42.63
Crk	102+			Weathered granite-gneiss		

Table 3. Chemical properties of pedon soils

Horizons	Depth(cm)	pH (1:2.5)		EC (1:25)(dSm^{-1})	CaCO3(g kg^{-1})	O.C.(g kg^{-1})
		Water	KCl			
Pedon 2						
Ap	0-17	7.59	7.05	0.25	35.00	4.20
B1w	17-43	7.61	6.45	0.28	36.25	2.48
B2t	43-63	7.99	5.91	0.47	25.00	2.29
BC	63-80	7.58	5.85	0.45	31.25	0.76
Cr	80+			Weathered granite-gneiss		
Pedon 3						
A1	0-7	7.45	6.22	0.04	30.00	5.34
Bw1	7-22	7.40	5.30	0.03	32.50	4.58
Bw2	22-43	7.58	5.61	0.05	41.25	3.05
Cr	43+			Weathered granite-gneiss		
Pedon 4						
Ap	0-14	7.10	5.75	0.09	27.50	4.20
B1w	14-47	7.33	5.58	0.07	28.75	4.01
B2t1	47-74	7.62	5.65	0.03	23.75	3.62
B2t2	74-104	7.56	5.81	0.02	30.00	3.62
Cr	104+			Weathered granite-gneiss		
Pedon 6						
Ap	0-20	6.57	6.05	0.09	22.50	3.43
Bw	20-41	7.45	6.82	0.49	22.50	3.24
BC	41-50	7.83	6.19	0.25	20.00	2.48
Cr	50-75+			Weathered granite-gneiss		
Pedon 9						
Ap	0-12	7.02	5.91	0.04	27.50	5.15
B1w	12-53	7.58	5.77	0.02	20.00	4.96
B2t	53-93	7.96	6.30	0.04	23.75	4.20
BC	93-107	7.84	6.64	0.04	20.00	3.81
Cr	107+			Weathered granite-gneiss		
Pedon 10						
Ap	0-20	7.45	6.49	0.21	21.25	4.58
Bss1	20-50	7.81	6.52	0.21	20.00	5.34
Bss2	50-70	8.50	7.07	0.36	28.75	3.62
BC	70-80	8.32	6.56	0.30	23.75	0.19
Cr	80+			Weathered granite-gneiss		
Pedon 11						
Ap	0-13	7.62	5.49	0.11	21.25	5.15
B1w	13-33	7.85	5.93	0.07	18.75	4.39
B2t1	33-77	7.68	6.05	0.09	21.25	4.58
B2t2	77-110	8.04	6.44	0.17	22.50	3.62
Cr	110+			Weathered granite-gneiss		
Pedon 13						
Ap	0-18	6.41	4.32	0.23	25.00	6.87
Bw1	18-37	7.06	5.46	0.05	32.50	3.81
Bw2	37-63	7.89	5.74	0.08	31.25	3.43
BC	63-72	7.67	5.85	0.12	26.25	2.67
Cr	72-85+			Weathered granite-gneiss		
Pedon 16						
Ap	0-13	7.23	5.21	0.05	31.25	6.87
Bw1						
13-30	7.74	5.44	0.06	26.25	4.96	
Bw2	30-51	7.81	5.25	0.03	36.25	2.86
BC	51-78	7.56	5.01	0.02	25.00	2.48
Cr	78-90+			Weathered granite-gneiss		
Pedon 17						
Ap	0-15	8.20	7.18	0.20	61.25	3.43
Bss1	15-50	8.63	7.14	0.31	87.50	2.10
Bss2	50-88	8.51	7.24	0.34	105.00	2.48
BCk	88-102	8.67	7.34	0.32	141.25	1.34
Crk	102+			Weathered granite-gneiss		

Table 4. Exchangeable cations and cation exchange capacity of pedon soils

Horizon	Depth(cm)	Exchangeable bases				CEC	Base saturation	Exch. sodium percent (ESP)
		Ca	Mg	Na	K			
		----------------	cmol (p+)kg-1	------------------				---------%---------
Pedon 2								
Ap	0-17	13.20	4.60	0.52	0.45	23.16	81.00	2.35
B1w	17-43	13.56	6.40	0.67	0.31	25.34	82.63	2.64
B2t	43-63	14.12	6.00	0.46	0.28	25.06	83.24	1.77
BC	63-80	8.20	5.20	0.34	0.23	16.97	82.32	1.83
Cr	80+					Weathered granite-gneiss		
Pedon 3								
A1	0-7	12.12	3.80	0.35	0.38	20.95	79.48	1.84
Bw1	7-22	13.25	3.60	0.48	0.31	21.44	82.27	2.23
Bw2	22-43	11.00	2.80	0.61	0.28	17.29	84.96	3.52
Cr	43+					Weathered granite-gneiss		
Pedon 4								
Ap	0-14	10.25	2.40	0.26	0.18	15.59	82.38	1.64
B1w	14-47	9.60	3.20	0.30	0.21	15.91	83.66	1.91
B2t1	47-74	13.40	3.60	0.48	0.31	20.89	85.16	2.29
B2t2	74-104	11.80	3.00	0.35	0.41	18.76	82.94	1.85
Cr	104+					Weathered granite-gneiss		
Pedon 6								
Ap	0-20	11.12	2.80	0.86	0.33	19.31	78.25	4.45
Bw	20-41	12.60	3.40	0.79	0.38	21.37	80.35	3.70
BC	41-50	10.26	3.60	0.68	0.23	18.51	79.80	3.67
Cr	50-75+					Weathered granite-gneiss		
Pedon 9								
Ap	0-12	10.23	3.80	0.35	0.29	17.09	84.24	1.96
B1w	12-53	11.20	4.40	0.61	0.31	19.02	86.85	3.20
B2t	53-93	12.60	2.60	0.48	0.31	17.90	89.30	2.67
BC	93-107	7.40	2.60	0.48	0.36	14.08	76.98	3.40
Cr	80+					Weathered granite-gneiss		
Pedon 10								
Ap	0-20	28.75	5.29	0.63	0.42	37.49	93.60	1.53
Bss1	20-50	36.34	5.62	0.81	0.36	46.33	93.09	2.13
Bss2	50-70	32.52	6.43	0.73	0.56	42.54	94.59	3.36
BC	70-80	20.05	4.60	0.54	0.28	26.96	94.47	1.31
Cr	80+					Weathered granite-gneiss		
Pedon 10								
Ap	0-13	9.82	3.00	0.32	0.26	16.00	83.75	2.00
B1w	13-33	10.60	3.40	0.41	0.41	17.02	87.07	2.56
B2t1	33-77	12.45	4.01	0.30	0.33	19.40	88.14	1.57
B2t2	77-110	13.82	4.53	0.48	0.28	23.56	81.11	2.03
Cr	110+					Weathered granite-gneiss		
Pedon 13								
Ap	0-18	8.40	3.40	0.62	0.21	12.73	83.50	4.87
Bw1	18-37	11.00	1.20	0.72	0.31	15.43	85.74	4.67
Bw2	37-63	16.40	6.20	0.68	0.46	24.84	95.57	2.74
BC	63-72	15.20	3.80	0.81	0.28	22.89	87.77	3.54
Cr	72-85+					Weathered granite-gneiss		
Pedon 16								
Ap	0-13	7.60	3.60	0.43	0.41	14.15	85.15	3.07
Bw1								
13-30	8.60	3.40	0.48	0.26	15.13	84.14	3.16	
Bw2	30-51	8.10	4.80	0.74	0.28	16.32	85.30	4.53
BC	51-78	7.20	5.00	0.70	0.33	16.43	80.52	4.23
Cr	78-90+					Weathered granite-gneiss		
Pedon 17								
Ap	0-15	29.42	7.23	0.65	0.33	41.23	91.28	1.53
Bss1	15-50	36.25	8.89	1.03	0.54	49.21	94.92	2.13
Bss2	50-88	32.07	10.36	1.41	0.28	46.76	94.36	3.37
BCk	88-102	20.54	7.68	0.39	0.23	29.12	99.05	1.31
Crk	102+					Weathered granite-gneiss		

classified as Vertisols at order level as these pedons did not have lithic or paralithic contact within 50 cm of soil surface and had a weighted average of >30 per cent clay in all the horizons down to a depth of 1 m and possessed cracks that open and close periodically. These pedons have a layer of >25 cm thicker, with in 100 cm from the soil surface that has slicken sides and wedge-shaped peds.

As the moisture regime is ustic, pedon 2, 3, 4, 9 and 11 were classified as Ustalfs at sub-order level. Pedon 6, 13 and 16 were classified at sub-order level as Ustepts. Similarly pedon 10 and 17 were classified as Usterts at sub-order level. Pedon 2, 3, 4, 9 and 11 did not have either duripan or calcic horizon and the base saturation was more than 60 percent at a depth between 0.2 to 0.7 m from the soil surface. These characters indicated that these pedons confirmed to the central concept of Ustalfs. So, these pedons grouped under Haplustalfs at great group level. Similarly, the pedons 6, 13 and 16 were keyed out as Haplustepts, as they do not have duripan, kandic and petrocalcic horizons. Pedon 10 keys out as Haplusterts at great group level as it does not have salic, gypsic or calcic horizon. Whereas, pedon 17 classified as Calciusterts at great group level due to presence of calcic horizon.

At the sub-group level, pedon 3, 4, 9 and 11 do not exhibit inter-gradation with other taxa or an extra-gradation from the central concept, hence keyed out as Typic Haplustalfs. Pedons 6, 13 and 16 keyed out as Typic Haplustepts, Similarly pedon 10 and 17 were classified as Typic Haplusterts and Typic Calciusterts, respectively. Whereas pedon 2 was classified as Inceptic Haplustalf due to an argillic horizon of less than 35 cm in thickness and no densic, lithic contact within 100 cm of mineral soil surface. Classification of selected pedons at family level was made based on the particle size class, CEC class, mineralogy class and soil temperature regime class. Pedons 2, 10, 11, 13, 16 and 17 contained more than 35 percent and less than 60 percent clay (weighted average) in the control section, which led the soils to be grouped under fine particle size class. Pedon 3 and 6 contained more than 35 percent clay and are in lithic contact so they are classified under clayey particle size class. Pedon 9 contained more than 18 percent and less than 35 per cent clay (weighted average) in the control section, hence keyed out as fine loamy.

Pedons 2, 6, 9, 11 and 13 were classified as active at cation exchange activity classes because the ratio of CEC to percent clay (by weight) was between 0.40 to 0.60. Pedon 16 was classified as semi active because the CEC to clay ratio was between 0.40 to 0.60, whereas pedon 10 and 11 were classified as active because the CEC to clay ratio was more than 0.60.

Table 5. Soil classification up to family level

Pedon	Soil classification upto family level
Pedon 4	Fine, mixed, active, isohyperthermic, Typic Rhodustalfs
Pedon 2	Fine, mixed, superactive, isohyperthermic, Inceptic Haplustalfs
Pedon 3	Clayey, mixed, active, isohyperthermic, Lithic Haplustalfs
Pedon 13	Fine, mixed, active, isohyperthermic, Typic Haplustepts
Pedons 6	Clayey, mixed, active, isohyperthermic, Typic Haplustepts
Pedon 9	Fine-loamy, mixed, active, isohyperthermic, Typic Haplustalfs
Pedon 10	Fine, smectitic, superactive, isohyperthermic, Typic Haplusterts
Pedon 11	Fine, mixed, active, isohyperthermic, Typic Haplustalfs
Pedon 16	Fine, mixed, semiactive, isohyperthermicTypic Haplustepts
Pedon 17	Fine, smectitic, superactive, isohyperthermic, Typic Calciusterts

MAST was computed from the MAAT (24^0C) by adding 3.5^0C, hence study area was classified under hyperthermic (MAST 27.5^0C) (Sehgal, 1996) and the difference between mean summer and winter temperature was less than 6^0C. Therefore, the temperature regime of the study area was classified as isohyperthermic. The cation exchange activity class of pedons under study was super active for pedon where CEC to clay content ratio exceeds 0.60 (Soil Survey Staff, 2014).

The study of morphological, physical and physico-chemical analysis of soil samples revealed that the soils of Balapur micro-watershed were shallow to deep in red soil pedons, whereas in black soil pedons it was moderately deep to deep. The colour of the soils in red soil pedons varied from dark reddish brown to yellowish red. In black soil pedons the colour varied from very dark brown to very dark gray. The texture of soils was found to vary from sandy clay to clay. Presence of argillic horizon was observed in pedons 2, 3, 9 and 11. Slickensides were very prominent in black soil pedons of 10 and 17.The structure was crumb to sub-angular blocky. The soils of Balapur micro-watershed were neutral to moderately alkaline in soil reaction, non-saline, non-calcareous and low in organic carbon content. Further CEC was also low to medium and exchange complex was dominated by Ca^{2+} The soils of micro-watershed were classified up to family level.

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